Section 4.0 DEVELOPMENT OF THE BASIC EMISSION RATES

This document describes the development of basic exhaust emission rates for gasoline fueled passenger cars, light-duty trucks and medium-duty trucks (under 8500 lbs.). An emission rate represents the amount of pollutant emitted in grams per mile. The model year specific emission rate is a composite rate that accounts for variation in emissions by vehicle technology, the distribution of clean to high emitting cars and differences between the emission rates for clean and high emitting vehicles.

4.1 Introduction

The underlying assumptions in EMFAC2000 are that the vehicle fleet can be categorized into unique technology groups with each technology group representing vehicles with distinct emission control technologies, that have similar in-use deterioration rates, and respond the same to repair. Further, vehicles in each technology group can be sub-divided into emission regimes. An emissions regime is defined such that emissions from vehicles within the regime do not increase with mileage accumulation. The emission regimes are analogous to quantum energy levels. The emissions characteristic of a vehicle technology group can be represented by these emission regimes, and vehicle deterioration can be simulated by the movement of vehicles among these regimes. In EMFAC2000, vehicles in each technology group are categorized into the following five regimes:

- Normals,
- Moderates,
- Highs,
- Very Highs,
- Supers.

In general, normal vehicles are those that maintain their emission levels at or below the vehicle's certification standards (FTP-standards). Moderate vehicles have emission levels that are between one and two times the FTP standards. Highs, very highs and super emission regimes have emissions levels that may be four, six and seven times the FTP standards, respectively. As vehicles age (or accumulate mileage), their emissions increase as a result of deterioration hence they migrate from normal emitting regimes to higher emitting regimes. The movement of vehicles into the higher emitting regimes is based on an analysis of CARB's in-use vehicle data, the final product of which is called the regime growth rates. This is discussed in more detail in section 4.5.

The following example illustrates how the model calculates the without I&M[1] hydrocarbon emission rates for 1966 model year vehicles in calendar year 1990. The intent of this example is to introduce the concepts of technology groups and emission regimes. The model first determines from the technology fraction file the type of vehicles sold in 1966 model year. Table 4-1 shows that vehicles sold in 1966 were equipped with two distinct technology groups.

[1] I&M Inspection and Maintenance or Smog Check. The intent of these programs is to lower in-use deterioration rate by identifying dirty vehicles and repairing them.

Table 4-1 Technology Groups Sold In 1966

Tech. Group	Tech. Group Description	1966 Model Year Sales
1	Non-catalyst vehicles without air injection	92%
2	Non-catalyst vehicles with air injection	8%

The model calculates the total mileage accrued by these vehicles in the1990 calendar year. In this example, it is assumed that these vehicles have accrued approximately 200,000 miles. This mileage is then used in estimating the distribution of vehicles by emissions regime. Table 4-2 shows the percentage of vehicles in technology groups 1 and 2 by emissions regime. The weighted emission rate for technology 1 and technology 2 vehicles is 10.2 g/mi. and 8.2 g/mi., respectively. These rates are then multiplied by the respective sales fractions to arrive at a weighted rate of 10.04 g/mi. This process is then repeated for all model years up to and including the 1990 model year. The model year specific emission rates are then multiplied by the mileage accrued by these vehicles in 1990 calendar year the summation of which results in an inventory for the 1990 calendar year.

Table 4-2 Regime Specific Populations and Emission Rates

Tech Group	Regime	Percent	Emissions (g/mi.)
1	Normal	0.0	3.1
	Moderate	83.3	5.9
	High	1.4	12.9
	Very High	7.8	26.6
	Super	7.5	40.9
	Weighted		**10.2**
2	Normal	34.3	4.0
	Moderate	50.5	5.3
	High	1.2	15.1
	Very High	7.1	23.8
	Super	6.9	33.6
	Weighted		**8.2**

In EMFAC2000, as in its predecessor model CALIMFAC, the without I&M emission rates are calculated first. The with I&M emission rates are calculated from the without I&M rates. Section 8.0 describes how the with I&M rates are calculated. This document only deals with the development of the without I&M rates.

This document describes the following:

1. Development of the vehicle technology groups. (Section 4.2)
2. Assessing technology groups that needed improvement. (Section 4.3)
3. Data used in developing the average emission rates for each technology group, by emissions regime. (Section 4.4)
4. Development of the emission regime boundaries and regime growth rates. (Section of 4.5)
5. Calculation of average emission rates. (Section 4.6)

6. UC based emission rates. (Section 4.7)

4.2 Vehicle Technology Groups

In MVEI7G, the CALIMFAC model was used in calculating the with and without I&M emission rates which were then used as inputs to the EMFAC model. The basic framework of EMFAC2000 is modeled after the old CALIMFAC model. The first step was to update the CALIMFAC's technology groups. In the CALIMFAC model the vehicle fleet was characterized into 16 technology groups (Table 4-3).

Table 4-3 Technology groups used in the CALIMFAC model

Technology Group	Model Years Included	Emission Control Systems
1	Pre-1975	Without Secondary Air
2	Pre-1975	With Secondary Air
3	1975 and later	No catalyst
4	1975-76	Oxidation catalyst, with secondary air
5	1975 and later	Oxidation catalyst, w/o secondary air
6	1977 and later	Oxidation catalyst, with secondary air
7	1977-79	TBI/Carb, TWC
8	1981 and later	TBI/Carb, single bed TWC, 0.7NOx
9	1981 and later	TBI/CARB, dual-bed TWC, 0.7 NOx
10	1977-80	MPFI, TWC
11	1981 and later	MPFI, TWC, 0.7 NOx
12	1981 and later	TBI/Carb, TWC, 0.4 NOx
13	1981 and later	MPFI, TWC, 0.4 NOx
14	1980	TBI/Carb, TWC
15	1993 and later	TBI/Carb, TWC, 0.25 HC and 0.4 NOx
16	1993 and later	MPFI, TWC, 0.25 HC and 0.4 NOx

During the early development of EMFAC2000, staff noted that the 1980 to approximately 1984 model year vehicles contributed disproportionately to the emissions inventory. Staff postulated that this phenomenon might be due to the introduction of prototype three-way catalysts, closed loop control, and fuel-injection systems on vehicles sold during these model years. If this hypothesis was true, then the technology groups 8, 9, 11, 12 and 13 should be further disaggregated since they encompassed 1981 and newer model years.

To prove this hypothesis, staff analyzed 1975 and later model year passenger car data from the: 2S76, 2S77400, 2S78C1, 2S79C1, 2S80C1, 2S81C1, 2S82C1, 2S83C1, 2S78C2, 2S80C2, 2S87C1, 2S88C1, 2S89C1, 2S89C2, 2S90C1, 2S92C2 and 2S93C1 light-duty vehicle surveillance projects using SAS software. The CARB routinely conduct surveillance projects in an ongoing effort to improve the motor vehicles emissions inventory. During these projects, vehicles are randomly selected from the Department of Motor Vehicles (DMV) vehicle registration database, procured, and tested as-is at baseline. Vehicles are tested using the FTP test procedure. In the surveillance projects listed above, the numbers after "S" refer to the calendar year during which the surveillance project was conducted. Since every project contains

a crossection of the vehicle fleet, the database contains emission data for vehicle model years tested at various mileages.
The entire data set, consisting of 3151 vehicles, was first disaggragted into technology groups 3 through 14. Tables 4-4 and 4-5 show the number, and mean odometer of vehicles by technology group and model year, respectively. Similarly, Tables 4-6, 4-7 and 4-8 show the mean FTP weighted HC, CO and NOx emissions by technology group and model year, respectively.

The objective of the analysis was to determine if HC, CO or NOx emissions from a given technology group vary from one model year to the next, taking into account the odometer of the vehicles when tested. Since the number of vehicles tested in each model year varied, an analysis of variance was performed using "Proc GLM" for unbalanced data sets on each technology group. The analysis of variance tests to determine if the null hypothesis (H_o) is acceptable or can be rejected in favor of an alternative hypothesis (H_a). In this analysis, the H_o is that the emissions within any technology group don't vary from one model year to the next. The H_a is that the emissions within any technology group vary from one model year to the next. If H_o is rejected then the Duncan's[2] multiple range test was performed at a 95% confidence level to determine what the differences are by model year, i.e., for a particular technology group are the mean HC emissions from 1981 to 1984 model year vehicles similar, but significantly different from 1985+ model year vehicles? Additional analyses were also performed to determine if:

a) The emissions from technology group 8 and 9 differ significantly from each other or do the emissions from combining the technology groups vary by model year.
b) The emissions from technology groups 12 and 13 differ significantly from each other or do the emissions from combining the technology groups vary by model year.
c) The emissions from technology groups 8, 9 and 11 differ significantly from each other or do the emissions from combining the technology groups vary by model year.

These analyses were performed to see if certain technology groups could be combined. The analysis indicated that vehicles in technology group 5 (1975 and later model year vehicles with oxidation catalyst and without secondary air) should be split into 1975-79 and 1980+ model year groups. The HC, CO and NOx emissions from the older model year grouping were higher than those from the newer model year grouping. Similarly, the analysis indicated that technology group 11 should be split into 1981-84 and 1985+ model year groups. Again, the HC, CO and NOx emissions from the older model year grouping were higher than those from the newer model year grouping. This analysis lent credence to the theory that there is a learning curve associated with the implementation of any new emission control technology. Following the same reasoning, staff also recommended that technology group 13 (1981 and later, MPFI, TWC equipped vehicles certified to the 0.4 NOx standard) be split into 1981-84 and 1985+ model year groups. This recommendation was based on engineering judgement and not based purely on data analysis. However, this was not done since it would have diluted the sample size, and diminished the significance of the analyses. Two analyses were performed for this technology group, one with and one without the 1987 model year vehicles since these vehicles had high emissions. Both analyses indicated that older model year vehicles (1983-84) behave differently than 1985+ vehicles, however, the results were not definitive due to insufficient data for 1985-87 model year vehicles.

[2] Multiple comparison procedures. An Introduction to Statistical Methods and data Analysis by Lyman Ott

Additional analyses indicated that there was very little difference between technology groups 4 and 6, both incorporate vehicles equipped with oxidation catalysts with secondary air injection. Ideally, these groups should be combined, however, staff suggested that technology group 4 encompass 1975-77 model year vehicles and technology group 6 should incorporate 1978 and later vehicles. This was done based on the visual interpretation of the mean HC and CO emissions and on the suggested grouping for NOx.

Additional analyses indicated that technology groups 8 and 9 were similar, and that the HC and CO emissions did not vary by model year. However, the Duncan's test indicated that the NOx emissions from 1981-85 vehicles varied significantly from the 1986 and later model year vehicles. This result was attributable to the 1986 and newer single-bed TWC vehicles having lower NOx emissions than the older model year vehicles and the dual-bed TWC equipped vehicles. A similar analysis was also performed on the 1981 and newer 0.7 NOx TBI/CARB single- or dual-bed TWC equipped vehicles to determine if the emissions very significantly by fuel delivery system. The results indicated that the weighted emissions do not vary significantly by fuel delivery system. Both analyses indicated that technology group 8 and 9 should be collapsed to form a more robust data set for subsequent analyses.

A similar analysis was also performed to see if technology groups 12 and 13 could be combined. The results indicated that the emissions varied significantly by technology group, i.e., the emissions from 0.4 NOx TWC equipped vehicles vary by TBI/CARB and MPFI fuel delivery systems.

The final analysis was to determine if technology group 11 was significantly different from technology groups 8 and/or 9. The results indicated that technology group 11 was significantly different from technology groups 8 or 9, and as such should remain as an independent technology group.

Table 4-9 shows the final technology groups used in EMFAC2000.

Having determined the technology groups, the next step in updating the basic emission rates was to see how well the CALIMFAC program did in predicting the population of vehicles in each regime when compared to the data from the new surveillance programs.

Table 4-4 Number of Vehicles by Technology Group and Model Year

Tech	MODEL YEAR																		
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
3	23	34	25	13	14	10													119
4	191	221																	412
5	37	47	18	22	23	9	20												176
6			216	187	137	69	27	37	44	2	1								720
7		1		6	17														24
8							109	60	82	90	67	55	44	34	16				557
9							46	94	59	90	60	23	2						374
10			4	2	9	38													53
11							38	42	45	56	79	77	48	50	20				455
12									35						13	8	3		59
13									9	13	2	1	2		29	18	5	5	84
14						118													118
																			3151

Table 4-5 Average Odometer by Technology Group and Model Year

Tech	MODEL YEAR																		
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
3	40069	31975	43180	41114	34126	29643													36949
4	42755	35987																	39125
5	41217	29657	51327	45824	35146	42126	50669												40067
6			38044	36431	34078	49587	43700	50632	69021	74747	32160								40822
7		51725		42169	43364														43414
8							54911	64383	82462	82857	70050	58238	66618	54756	43675				67245
9							48309	43960	61682	56796	54184	34342	34403						51377
10			51724	56255	32485	65517													58517
11							57481	87348	88668	84584	60303	54117	67497	47236	55289				66413
12									65171						52665	49610	34255		58733
13									80754	61835	39612	41987	73521		52297	43567	38887	22557	52463
14						46705													46705
																			50153

Table 4-6 Mean Hydrocarbon Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	1.963	1.108	2.58	1.004	0.934	0.619												
4	1.558	1.35																
5	2.751	1.609	1.906	2.255	1.367	0.679	0.484											
6			0.978	0.966	0.851	0.972	0.708	0.419	0.784	0.909	0.308							
7		1.69		1.659	1.396													
8							1.24	0.936	1.401	0.843	0.697	0.652	0.578	0.551	0.339			
9							0.869	0.866	0.804	0.869	0.945	0.512	0.716					
10			0.963	0.508	1.722	0.996												
11							0.768	1.029	1.001	0.892	0.646	0.523	0.402	0.348	0.335			
12									0.695						0.58	0.518	0.262	
13									0.87	0.483	0.306	0.275	1.002		0.371	0.394	0.235	0.245
14						1.192												

Table 4-7 Mean Carbon Monoxide Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	18.63	12.42	20.74	11.72	8.206	8.864												
4	20.38	14.57																
5	41.32	24.04	28.647	28.87	16.35	5.781	6.604											
6			13.37	12.51	11.3	13.35	13.01	7.04	14.01	20.78	8.77							
7		6.31		21.122	18.077													
8							18.375	13.86	15.727	11.029	11.027	13.62	9.386	8.551	6.445			
9							10.735	13.248	9.454	10.679	13.162	5.506	11.725					
10			21.08	5.73	10.843	13.341												
11							11.526	14.824	14.068	12.613	7.947	6.563	4.341	3.881	4.455			
12									9.4713						9.531	8.565	3.643	
13									11.443	5.716	4.17	2.36	8.22		4.019	5.035	2.902	2.516
14						20.56												

Table 4-8 Mean Oxides of Nitrogen Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	1.635	2.116	1.93	1.745	1.686	1.304												
4	2.481	2.395																
5	2.452	2.197	1.868	2.271	1.913	1.108	0.861											
6			1.837	1.611	1.671	1.198	0.895	0.774	1.063	1.042	0.33							
7		1.26		1.373	1.44													
8							1.051	0.988	1.395	1.063	0.73	0.752	0.712	0.668	0.514			
9							1.024	0.985	1.263	1.026	1.072	0.911	0.679					
10			1.581	1.05	1.341	1.561												
11							1.066	1.306	1.283	1.222	0.954	0.695	0.752	0.56	0.49			
12									0.865						0.723	0.708	0.303	
13									1.232	0.654	0.767	0.56	1.277		0.402	0.344	0.29	0.285
14						1.295												

Table 4-9 EMFAC2000 Technology Groups

Technology Group Definitions for EMFAC2000 and Corresponding Technology groups			
Old Group	Tech Group	Model Years Included	Emission Control Configurations, Fuel Metering Systems, and Applicable Emission Standards
1	1	Pre-1975	Without secondary air
2	2	Pre-1975	With secondary air
3	3	1975 and later	No catalyst
4	4	1975-1976	Oxidation catalyst, with secondary air
5	5	1975-1979	Oxidation catalyst without secondary air
	6	1980 and later	Oxidation catalyst without secondary air
6	7	1977 and later	Oxidation catalyst, with secondary air
7	8	1977-1979	Three-way catalyst with TBI/Carb
8 and 9	9	1981-1984	Three-way catalyst with TBI/Carb, 0.7 NOx
	10	1985 and later	Three-way catalyst with TBI/Carb, 0.7 NOx
10	11	1977-1980	Three-way catalyst with MPFI
11	12	1981-1985	Three-way catalyst with MPFI, 0.7 NOx
	13	1986 and later	Three-way catalyst with MPFI, 0.7 NOx
12	14	1981 and later	Three-way catalyst with TBI/Carb, 0.4 NOx
13	15	1981 and later	Three-way catalyst with MPFI, 0.4 NOx
14	16	1980 only	Three-way catalyst with TBI/Carb
15	17	1993 and later	Three-way catalyst with TBI/Carb, 0.25 HC
16	18	1993 and later	Three-way catalyst with MPFI, 0.25 HC
none	19	1996 and later	Three-way catalyst with TBI/Carb, 0.25 HC, and OBD II
none	20	1996 and later	Three-way catalyst with MPFI, 0.25 HC, and OBD II
none	21	1994-1995	Transitional Low Emission Vehicles (TLEV), **no** OBD II
none	22	1996 and later	TLEVs with OBD II
none	23	1996 and later	Low Emission Vehicles (LEV)
none	24	1996 and later	Ultra-Low Emission Vehicles (ULEV)
none	25	1996 and later	Zero Emission Vehicles (ZEV)
none	26	1996 and later	Three-way catalyst with TBI/Carb, 0.7 NOx, and OBD II
none	27	1996 and later	Three-way catalyst with MPFI, 0.7 NOx, and OBD II
none	28	All	Low Emission Vehicles (LEV II)
none	29	All	Ultra-Low Emission Vehicles (ULEV II)
none	30	All	Super Ultra-Low Emission Vehicles (SULEV)

TBI/Carb: Throttle-body injection or carburetor fuel metering system
MPFI: Multi point fuel injection system
OBD II: Second generation on-board diagnostic systems. All 1996 and later vehicles (except Mexican vehicles) are assumed to be equipped with OBD II.
*Supergroups: (A) Non catalyst, (B) Oxidation catalyst, (C) Three-way catalysts with carburetors or throttle body injection, (D) Three-way catalysts with multi point fuel injection